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(12) PATENT SPECIFICATION
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1

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(56) 1. French application no. 254097, cl. G 01 V 3/12, 1984.
2. U.S.S.R. inventor's certificate no. 1062631, cl. G 01 V 3/04, 1983

(54) METHOD OF GEOELECTRICAL PROSPECTING

(57) For geophysical studies, use of the methods of forming an electromagnetic field. Essence of the invention: the medium to be studied is excited by means of inducing electrical current in the earth with the aid of power-supply electrodes. One of the electrodes is grounded in the central part of the circle formed by other evenly grounded electrodes. Current to the latter is brought from the central part of the circle with the aid of radial segments situated along radii of the circle at equal angles, and additional segments, of power-supply lines. The additional segments are of equal length that is a multiple of the distance along a straight line or along an arc between adjoining electrodes. The latter are grounded along the circumference so that the totality of additional segments of power supply lines forms a loop. Measurements are simultaneously made of the radial-electrical and vertical-magnetic components of the electromagnetic field. Radial data are used to make judgments about the properties of the medium being studied. 2 illustrations.

3

The invention relates to geoelectrical prospecting and may be used to conduct searches for geological features, especially hydrocarbons, using methods of forming an electromagnetic field.

A method for electrical prospecting is known [1] in which the probing signal is formed as a code of special frequencies using a lattice system of transmitting electrodes and inductive loops situated above deposits of hydrocarbons and zones without deposits; a signal is measured that is directed in measurement electrodes and inductive antennas situated within the transmitting system. Using a processor, images of reservoirs are identified and analyzed, followed by prospecting measurements and determination of the significance of the resources for each measurement point.

With this method of geoelectrical prospecting, vortex currents are created in the investigated medium. These currents are variously oriented mainly in horizontal planes, which makes it more difficult to do searches for extended, thin, poorly transmitting media of the "reservoir" type, which are effectively delineated using the probing field oriented in the vertical plane.

One method [2], which is closer to the proposed means of geoelectrical prospecting, consists of exciting an electromagnetic field in the investigated medium by axisymmetrical introduction of electrical current in the earth using power-supply electrodes, one of which is placed in the central part of a circle formed by other power-supply electrodes. Measurements are made of the formation parameters of the electrical component of the field according to profiles that diverge radially from the center of the circle. According to the results of measurements, judgments are made about the structure and properties of the investigated medium.

This method permits vortex currents to be created in the investigated medium, which are closed mainly in vertical planes. This permits high-resolution delineation of "reservoir"-type objects. However, the method is not effective under conditions where the investigated object is covered by high-resistance screens, i.e., where it is necessary to create vortex currents that are closed in vertical planes in the investigated medium. Combining such a method with known ones, such as the transient-processes method, results in unavoidable increases in the expense of conducting additional investigations. Thus, the method does

ensure excitation of vortex currents in the investigated medium that are closed both in the vertical and in the horizontal planes. This does not allow the resolution of geophysical investigations to be improved without increased energy expenditures.

The invention being patented is directed toward solving the problem of increasing resolution of geophysical investigations without increasing energy expenditures, by ensuring simultaneous excitation of vortex currents in the investigated medium that are closed both in the vertical and in the horizontal planes.

The essence of the invention consists of a method for geoelectrical prospecting in which the investigated medium is excited by introducing electrical current in the ground using power-supply electrodes. One of these electrodes is grounded in the central part of a circle formed by other evenly-grounded electrodes. Current is brought to these other electrodes from the central part of the circle using radial segments of a supply line, situated along radii of the circle at equal angles. Measurements are made along radial profiles of parameters of the electrical component of the electromagnetic field caused by a reaction of the investigated medium to excitation. According to the data obtained, judgments are made of the properties of the investigated medium. A proposal is made to bring current to the power supply electrodes grounded along the circumference from the outer ends of the radial power-supply segments using additional segments of a power-supply line that are of equal length that is a multiple of the distance along a straight line or along an arc between adjoining electrodes. These are grounded along the circumference so that the totality of additional segments of the power-supply line can form a loop, and they measure the parameters of the magnetic component of the electromagnetic field.

In a manner being patented, current is supplied to each electrode grounded

around the circumference, using corresponding radial and additional segments of the power-supply line, permitting two mutually orthogonal configurations of an electromagnetic field to be be excited simultaneously. The electrical component of the field is measured along the radial profiles, and will be free from influence from the field induced by the loop formed by the entire totality of additional segments of the power-supply line. At the same time, measurements

of the magnetic component will derive only from the field excited by this loop. Consequently, simultaneous excitation of vortex currents is ensured in the investigated medium. These currents are closed both in the vertical and in the horizontal planes; independently, components of the electromagnetic field derived from these vortex currents are registered independently, permitting higher resolution of the investigations without increasing energy expenditures.

Figures 1 and 2 present versions for implementing the power-supply device for instances in which $n<N$ and $n \geq N$, respectively.

The device that implements the method contains a source 1 of current, to one pole of which a power-supply electrode 2 is connected. This is grounded in the center of the circle formed by evenly grounded power-supply electrodes 3, which are connected to the other pole of power-supply source 1 with the aid of corresponding radial segments 4, situated at angles along the radii of the circle, and additional segments 5, situated along the circle. Detectors 6 that measure the electrical component of the field are situated axisymmetrically; for example, on radial profiles that are a continuation of radial segments 4 of the power-supply line. Each detector 6 is attached to a corresponding device 7 that measures the electrical component of the field. Detectors 8 of the magnetic component of the field are situated axisymmetrically, for example, between profiles for observation of the electrical component. Each detector 8 is connected to the corresponding device 9 for measurement of the magnetic component of the field.

An excitation generator can be used as a source 1 of current; its circuit diagram is presented in the book "Geophysical and geodesic methods and means in searching for Siberian minerals," published by the Siberian Scientific Research Institute of Geology, Geophysics and Mineral Raw Materials, 1982, pp. 46-50.

The radial segments 4 and additional segments 5 of the power-supply line are made of a GSMS geophysical wire.

Reception lines are one example of an electrical-field detector 6 that can be used, while measurement loops or magnetometers can be used as detectors 8 of magnetic fields.

In the capacity of detectors 7, 9 of the electrical and magnetic components of the field, Cycle-4 electrical prospecting devices (TU 41-04-1432-89) can be used.

The method is implemented in the following manner.

Before starting operations that derive from specific tasking, based on the results of mathematical modeling according to *a priori* data on the investigated site, or from the results of preliminary experimental work, parameters are selected for the power-supply device. To be specific, selections are made of the number N of power-supply electrodes 3, evenly grounded around the circumference, and the size of the radius R of the circle, i.e., the number and length of radial segments 4 of the power-supply line, the length l of additional segments 5 of the power-supply line, and also the magnitude of currents in the power supply line - current Ip of the loop formed by the additional segments 5 of the power-supply line, current I_1 in the radial segments 4 of the power-supply line, and the current Ii of the power source 1.

One of the basic conditions for implementing the proposed method is to introduce current in axisymmetric fashion into the ground. In practice this can be implemented at N≥6, since, at N=6, the electrical component of the electromagnetic field begins to attenuate in noticeable fashion. The upper limit of the values is bounded by the appropriateness of increasing the amount of unwinding operations.

The quantity R is determined within the limits 100+1000 m in dependence on the assigned depth of investigations. The quantity of currents Ip, I_1 Ii of the power-supply device is also determined by the depth of investigations and, additionally, the potential capabilities in using power source 1.

We cannot fail to emphasize that in the proposed method, investigations are carried out by the method of vertical probing simultaneous with studies using the method in which a field is formed. Generally, the depth of investigations according to the vertical probing method, which is provided by I_1 in the radial segments 4 of the power-supply line, might not coincide with the depth of investigations according to the method in which a field is produced, which is provided by In current of the loop. Therefore, an adjustment of the interrelations of currents In and I_1 takes place, using the coefficient of proportionality n. It is also evident that to ensure that current In of the loop remains constant, the length l of additional segments 5 must be a multiple of the distance along a straight line or arc between adjoining electrodes 3, which are grounded along the periphery. In other words, in the latter instance, it is a multiple of the quantity 2πR/N, and amounts to

[insert mathematical expression]

With this, the current In of the loop is determined according to the formula

$$I_n = [\text{insert}] + I_i = [\text{insert}] \cdot n,$$

where n = 1, 2, 3....

The upper limit of values for the coefficient n is limited by the increase in resistances of wires of the additional segments 5. In dependence on the selected value of the coefficient n, two versions are possible for the relation of currents In and Ii:

$I_n < I_i$ where $n<N$

$I_n \geq I_i$ where $n \geq N$,

to which correspond the versions for implementing the power-supply device as presented in figures 1 and 2.

For example, under conditions of geoelectrical profile cut that are typical of the eastern edge of the Western Siberian Platform, the total conductance to the base amounts to 300-400 S, but the depth to the base does not exceed 2000 m. This is shown by theoretical investigations and *in situ* experiments. Under such conditions, it is necessary to ensure the following values for the device's parameters:

$R = 500$ m; $N=6$; $In = Ii = 60A$; $n=6$; $l = 3140$ m.

This corresponds to the version for implementing the power-supply device as presented in figure 2, where the loop is formed by a six-strand cable, each strand of which is an additional segment 5 of the power-supply line, broken and connected by one lead to the corresponding power-supply electrode 3. By the other lead it is connected with the outer end of the nearest radial segment 4 of the power-supply line.

After determining the parameters of the power-supply device, it is set up at the investigated sector and excites an electromagnetic field in the investigated object by directing an electrical current into the ground as generated by power supply source 1. This current is then brought to the electrodes 3 that are grounded along the circumference with the aid of radial segments 4 and additional segments 5 of the power-supply line. Upon turning

the current off in the power-supply line, electromagnetic field parameters are measured which are the result of a reaction of the investigated medium to excitation. The electrical component is detected by detectors 6, which in this instance are reception lines whose length is not less than 500 m. The electrical component is measured by measuring devices 7. The radial electrical component as measured is derived only by the field created by radial segments 4 of the power-supply line, and does not depend on the field created by the loop formed by the totality of additional segments 5. The magnetic component is detected by detectors 8, which in this instance are reception loops with an effective area of 500,000 square meters (for example, three coils, 400 x 400 m), and is measured using measuring devices 9. In the event of a horizontally layered profile cut, measurements of the vertical magnetic component are determined only by the field that is created by the loop formed by the totality of additional segments 5 of the power-supply line. They are not dependent on the field created by radial segments 4 of the power-supply line. Data obtained in measuring the electrical component are interpreted, for example, by the methodology presented by V. S. Mogilatov in his article "A circular electrical dipole - a new source for electrical prospecting," in the Journal *Earth Physics*, no. 6, pp. 97-106. Magnetic data may be interpreted

according to the typical methodology of ZSB-MPP.

Simultaneous magnetic and electrical measurements permit both objects of study that are covered by high-resistance screens and "reservoir"-type objects to be delineated with a high degree of reliability. This enhances the resolution of geophysical investigations without increasing energy expenditure.

PATENT CLAIM

Method for geoelectrical prospecting, in which the investigated medium is excited by introducing electrical current into the earth using power-supply electrodes, one of which is grounded in the central part of a circle formed by other evenly grounded electrodes, current to which is brought from the central part of the circle with the aid of radial segments of a power-supply line situated along the radii of the circle at equal angles, measuring along radial profiles parameters of the electrical component of an electromagnetic field that derives from the reaction of the investigated medium to excitation, and allowing judgments to be made regarding its properties according to received data,

characterized in that

to the power-supply electrodes grounded along the circumference, current is brought from the outer ends of radial segments of the power-supply line, using additional segments of the power supply line, having equal lengths that are a

9

multiple of the distance along a straight line or along an arc between adjoining electrodes that are grounded along the circumference so that the totality of additional segments of the power-supply line form a loop, and

10

measure the parameters of the magnetic component of the electromagnetic field.

Fig. 2.

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